EFFECTS OF SPECTRAL BALANCE ON ANNOYANCE AND PERCEIVED QUALITY FROM INTERIOR HEAVY TRUCK SOUNDS

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Abstract

Drivers of heavy trucks are exposed to relatively high level of low frequency noise, causing negative responses such as significantly decreased wakefulness and general annoyance but also positive responses like the impression of powerfulness. Previous research indicates that one important property of the interior sound influencing these responses is the spectral balance. As an initial study a number of test participants were presented four different sounds either through a headphones-subwoofer combination, or through the subwoofer alone. The subwoofer has an upper cut-off frequency of 70Hz and a fall-off of -12dB per octave. The two different cases allow a low and high frequency (LF+HF) stimuli versus just low frequency (LF) stimuli set-up. Comparison of the results from the two cases show the following main effects: higher ratings for adjectives "Annoying" and "Quality" and lower ratings for adjectives "Pleasant" and "Valence" for the LF case. In addition the interaction effect that there was a decrease in differences between sounds in the LF case for adjective "Valence" and, however not statistically significant, a tendency that the order or precedence of the stimuli for adjective "Powerful" was shifted. Generally, the frequency balance is of great importance for annoyance and perceived quality.

1. Introduction

To date most research on low frequency noise in general, including interior truck sound, has been concerning negative aspects such as annoyance [1]. Manufacturers of heavy trucks try to lower noise levels to reduce negative responses. This is done with restraints about cost and weight. Soon the limit for what can be done within these frames has been reached and therefore it is of interest to find ways to make the sound less annoying without needing the level further. In addition, for any given product, both the manufacturer, who wants his product desirable, and the customer or user, who wants the product to fulfill his expectations, find it desirable to increase comfort and perceived quality [2]. Since a truck is a working environment for the driver, and the sound a part of the tools he uses to perform his duties, e.g. listening to make sure the engine is running properly, the sound should communicate the needed information. In a previous study the role of LF sound for annoyance, wakefulness and perceived quality in a heavy truck context was investigated, and some factors important for assessing interior truck sound were found [3]. An additional property of great interest is the so called spectral balance, i.e. the balance between low and high frequency content. Previous research has resulted in two aspects of the spectral shape of a sound to be especially important; the cut-off point and the slope [4]. The cut-off point is were the level of the sound starts to fall with increasing frequency. The slope is the rate at which the level falls with increasing frequency (Figure 1).

![Figure 1: Example of a spectral balance curve. In this case the cut-off point is at 75Hz and the slope is 12dB/oct.](image_url)
Table 1: Stimuli and adjective scales included in the listening test. The stimuli consist of the original recorded sound (RS1), and the recorded sound with added pure tones (RS1_30Hz_sin and RS1_60Hz_sin) and with added low pass filtered white noise (RS1_30Hz_lp).

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Adjective</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS1</td>
<td>Annoying</td>
<td>Unipolar: 0 - 9</td>
</tr>
<tr>
<td>RS1_30Hz_lp</td>
<td>Pleasant</td>
<td>Bipolar: (-5) - 5</td>
</tr>
<tr>
<td>RS1_30Hz_sin</td>
<td>Tiring</td>
<td>Unipolar: 0 - 9</td>
</tr>
<tr>
<td>RS1_60Hz_sin</td>
<td>Powerful</td>
<td>Unipolar: 0 - 9</td>
</tr>
<tr>
<td></td>
<td>Rumbling</td>
<td>Unipolar: 0 - 9</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>Unipolar: 0 - 9</td>
</tr>
<tr>
<td></td>
<td>Valence</td>
<td>Graphical Scale, 9 steps</td>
</tr>
<tr>
<td></td>
<td>Activation</td>
<td>Graphical Scale, 9 steps</td>
</tr>
</tbody>
</table>

As expected the analyses resulted in main effects such as that without the HF content the sound was by the participants rated more annoying, less pleasant and was perceived as giving an impression of higher quality (Table 2). The participants also rated themselves feeling slightly more positive, i.e. higher rated valence, with the high frequency content included. In addition to these main effects, some interactions are also worth noting.

As can be seen, the 'order' of the stimuli changes between LF and LF+HF, i.e. for some stimuli the sound becomes more annoying without the higher frequencies, and for others is becomes less annoying, although the overall mean in higher with higher frequencies. This pattern can be seen for all the other adjectives as well, and for the rated valence the variation between the stimuli is much smaller without the high frequency contents.

4. Conclusions
The main effects clearly suggest that, as expected, a proper frequency balance might reduce annoyance and other negative responses. Additionally it is interesting to investigate the interactions. One explanation to the high statistical significance of the rated valence (Table 2) could be that the variation between the stimuli is comparatively large with LF+HF but very small with only LF,
although the mean values do not differ very much between LF and LF+HF. This might suggest that the participants more easily could perceive the differences between the sound and thereby respond to them. The interaction effects show a consistent pattern for adjectives annoying, pleasant, valence and quality. Note that the RS1_60Hz_sin stimulus was rated similarly to the original recorded sound, RS1, for all the adjectives although sometimes somewhat emphasized. For the other two stimuli the order is switched, i.e. for some stimuli LF is worse than LF+HF and for the other it’s the other way around. Considering that the pattern exists for e.g. the adjective powerful, which is generally connected to the low frequency contents, emphasizes the importance of the spectral balance to annoyance and perceived sound character. This will be further investigated in combination with other properties.

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6. References


